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The Red Dog Deposit, Northwestern Alaska: Discovery, Delineation, and Development Implications

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Abstract

The Red Dog mineral deposit is located about 90 miles north of Kotzebue, Alaska. Ore reserves approximate at least 85 million tons, with grades of 17.1 percent zinc, 5.0 percent lead, and 2.5 ounces of silver per ton. There are also indications of additional mineralization of similar character in the vicinity, as well as elsewhere in the region. Geologic terranes similar to the Red Dog environs persist to the north and east, and occurrences of base and precious metal mineralization have been reported at several locations, particularly within the National Petroleum Reserve in Alaska (e.g., Drenchwater, Kivliktort, Story Creek). These, as well as geochemical anomalies across the region, remain to be elucidated in terms of resource potential.

The history of events which led to recognition, delineation, and development affords an important example for similar future endeavors, in context of present and future concerns and policies regarding continuing need for mineral resources to meet the requirements of society.

1. Introduction

The Red Dog mineral deposit is located in the DeLong Mountains, northwestern Alaska, about 90 miles north of the village of Kotzebue, and some 600 air miles from Anchorage. *Figure 1* shows the location (from Moore et al, 1986).

The Red Dog deposit has been described a number of times in the recent literature (e.g., Einaudi and Hitzman, 1986; Giegerich, 1986; Moore et al., 1986; Lange et al., 1985; Tailleur, 1970; WGM Inc., 1978; Mowatt, 1989; Mowatt, et al, 1990). Much of the present discussion is based on these sources, as well as the senior author's personal experience.

The deposit is in permafrost terrane, at an elevation on the order of 1,000 feet above sea level, surrounded by rolling hills, and adjacent higher mountains to the north and east. The deposit is named after Red Dog Creek, which flows directly across it. The creek bed, banks, and surrounding rocks are intensely-stained in red-orange colors, due to weathering of the mineralized bedrock.

Vegetation in the deposit area is generally low brush and muskeg, with growth largely inhibited on and peripheral to mineralized

bedrock zones. Red Dog Creek naturally contains high levels of various metallic elements, particularly zinc and cadmium. The pH of the water may drop below 5 during summer months, and the creek does not support recognized normal plant or aquatic animal life. The geochemical anomaly derived naturally from the deposit has been detected at least 25 miles downstream, to the confluence of Ikalukrok Creek and the Wulik River.

Most surface rock exposures in the deposit area are essentially outcrops-subcrops of rubbly materials, derived via permafrost weathering processes. The deposit area appears to have been glaciated, but oxidation of sulphides has been recognized to depths on the order of twenty feet or more.

Current interpretations of the regional geology of northwest Alaska consider the DeLong Mountains to be comprised of a series of eight stacked and folded thrust allocthons, the six structurally lowest of which consist of Devonian-Cretaceous clastic and chemical sedimentary rocks. The Red Dog deposit occurs in the second lowest of these allocthons, in black siliceous shale and chert, and associated minor carbonate rocks of Mississippian- Pennsylvanian age. *Figure 2* shows regional tectonic relationships, while *Figure 3* presents the distribution of known mineral deposits and occurrences of Devonian-Mississippian and Cretaceous age in northern Alaska and adjacent Canada. Both figures are from Einaudi and Hitzmam (1986).

Major types of ore occurrence at Red Dog include: (1) disseminated and stratiform sulphides thinly bedded in carbonaceous shale and chert of Mississippian-Pennsylvanian age; (2) massive sulphide veins-breccia fillings in silicified shale of similar age; (3) stratiform sulphide-bearing lenses, including quartzose material containing up to several percent sulphides and barite, and massive quartz-sulphide lenses containing up to several percent barite, and barite-quartz lenses with up to several percent sulphides. There are associated tuffaceous-volcanic rocks as well. The ore minerals occur in zones of various extents and thicknesses. Projected ore reserves approximate at least 85 million tons, with grades of 17.1 percent zinc, 5.0 percent lead, and 2.5 ounces of silver per ton.

The deposit is a strata-bound accumulation of silica rock, barite, and sulphides–principally sphalerite, pyrite, marcasite, and galena. Ore textures are various, including vein, fine-grained, massive, fragmental, poorly-bedded, or chaotic. The deposit probably formed by some combination of sea floor deposition and/or replacement or pre-existing sediments/rocks. Formation may have been related to igneous activity, directly or indirectly.

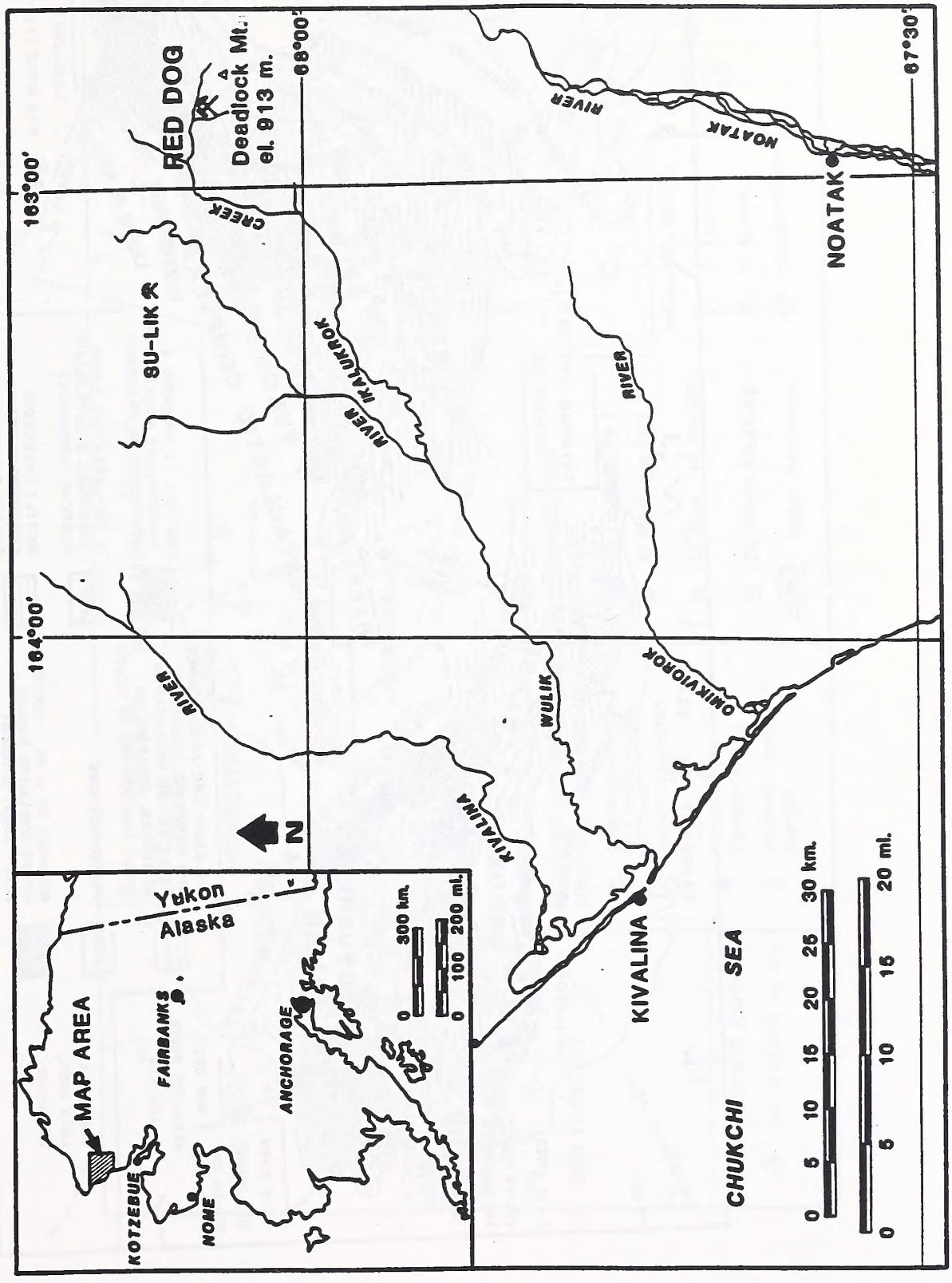

Figure 1. Location map showing the Red Dog mineral deposit (from Moore et al., 1986).

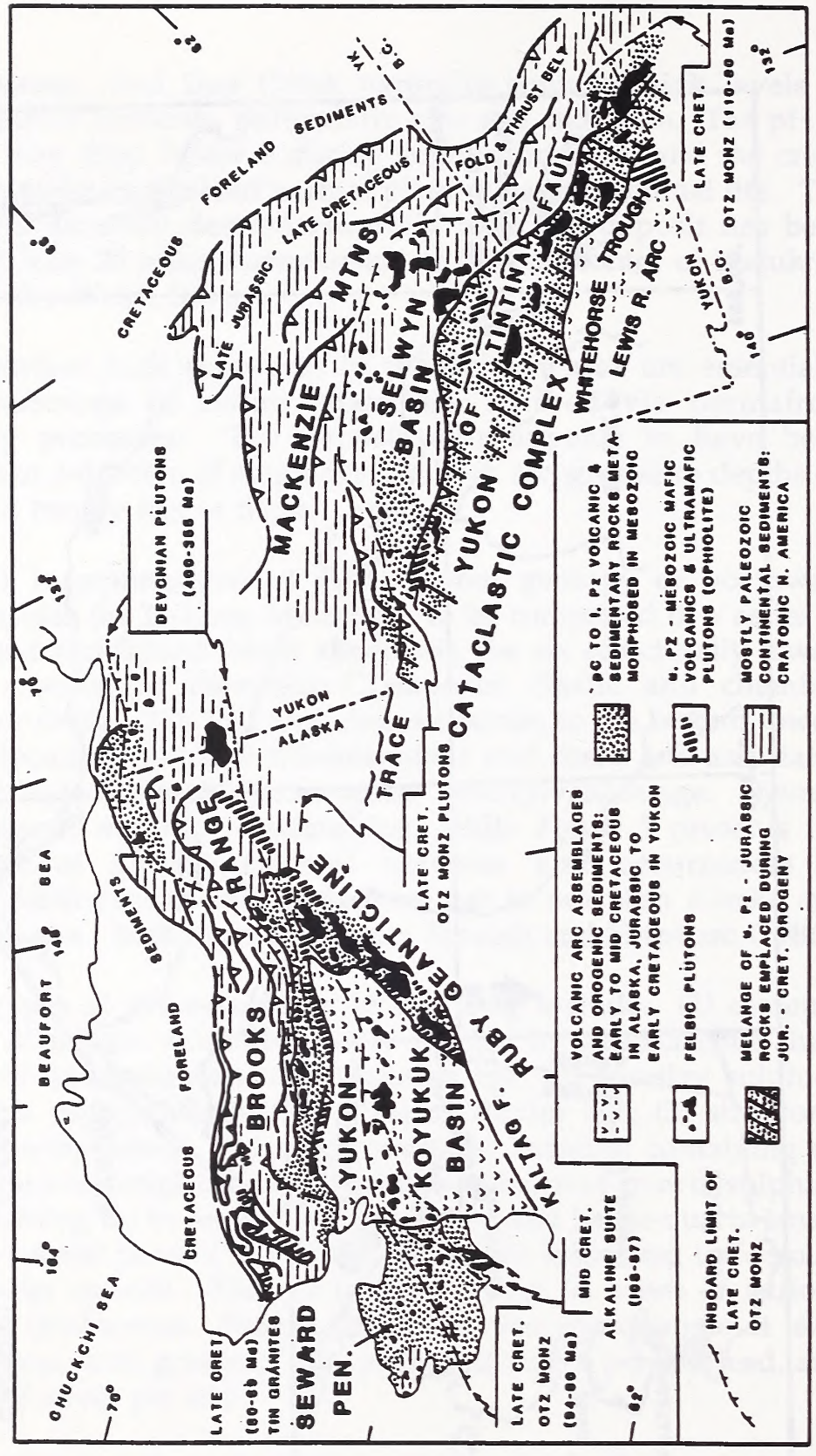

Figure 2. Tectonic map of northern Alaska and northern Canadian Cordillera for the middle Paleozoic to late Cretaceous (from Einaudi and Hitzman, 1986).

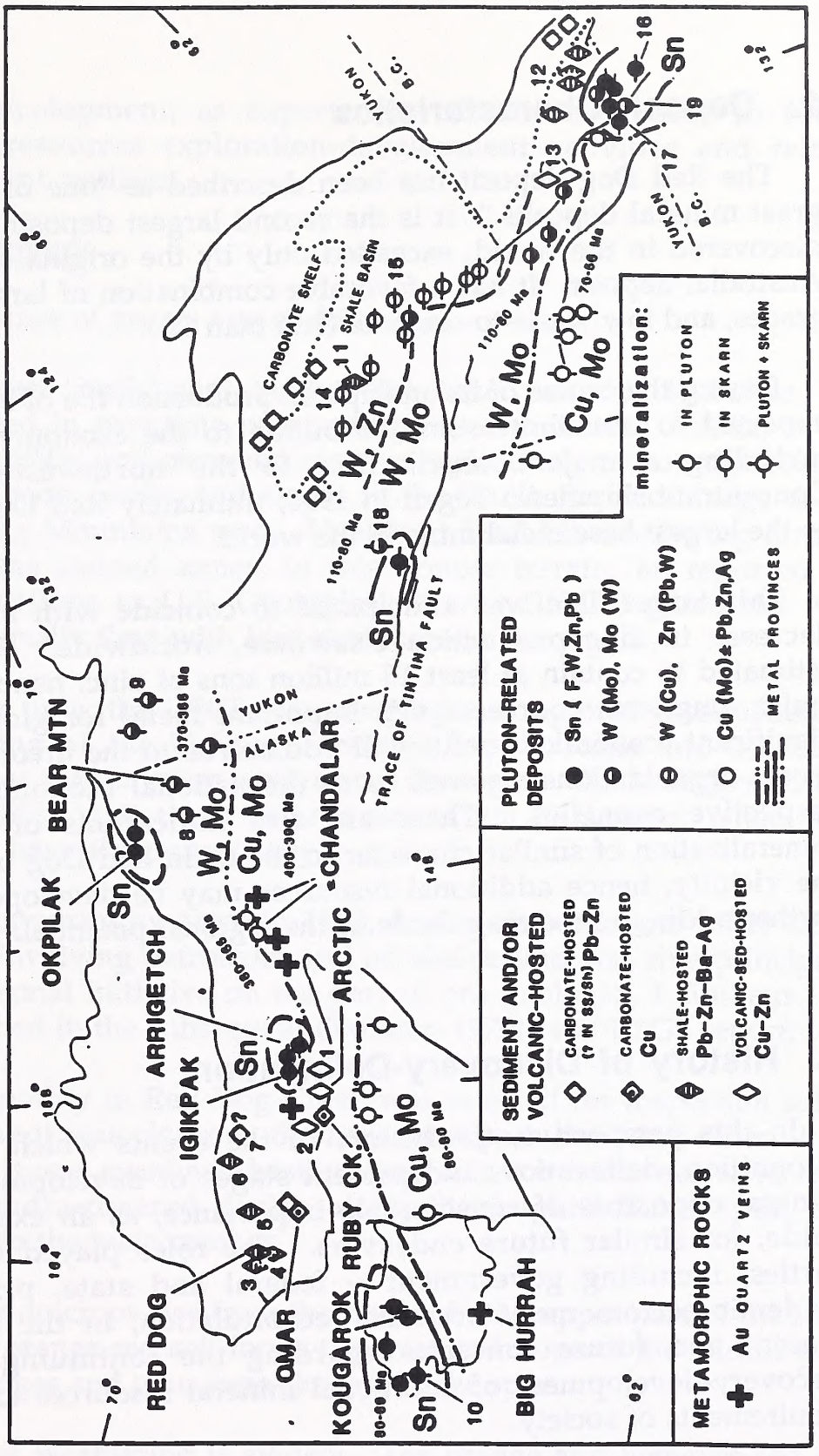

Figure 3. Distribution of mineral deposits and occurrences of Devonian-Mississippian and late Cretaceous age in northern Alaska and adjacent Canada. Note Red Dog location, northwest Alaska (from Einaudi and Hitzman, 1986).

2. Deposit Characteristics

The Red Dog deposit has been described as "one of the world's great mineral deposits." It is the second largest deposit of zinc ever discovered in the world, exceeded only by the original Broken Hill, Australia, deposit. It has a favorable combination of large size, high grades, and low waste-to-ore ratio (less than 1:1).

During the course of its anticipated production life of 50 years, it is expected to contribute some $5 billion to the economy of Alaska, including a major contribution to the northwestern region. Concentrate shipments began in 1990; ultimately Red Dog will rank as the largest base metal mine in the world.

This target date was anticipated to coincide with a significant decrease in zinc production elsewhere, worldwide. Red Dog is estimated to contain at least 15 million tons of zinc, hence, will be a major long-term source of this important metal for global society. Significant economic benefits will also accrue to the involved private sector organizations, as well as to the national economies of their respective countries. There are also indications of additional mineralization of similar character to the main Red Dog ore-body, in the vicinity, hence additional resources may be developed as well, further adding to the magnitude of the regional potential.

3. History of Discovery-Delineation

In this perspective, the history of the events which led to the recognition, delineation, and present stages of development of this mineral deposit is of considerable importance, as an example, and guide, for similar future endeavors. The roles played by various parties, including government -- federal and state, private, and academic sectors merit accurate recapitulation, in the context of present and future concerns regarding the continuing need for discovery-development of additional mineral resources to meet the requirements of society.

There have been several somewhat conflicting versions promulgated regarding the "discovery-recognition" of this deposit. Some of this hinges on semantics/definitions, as well as on a certain amount of assertions put forward for various reasons. It is felt that it is important to attempt to clarify this situation, and to document the actual course of events, given the significance of the Red Dog deposit, and the need for accurate appreciation of the events which have led

to its development, as experiences of potential value to future mineral resources exploration-development activities and related government policies.

A. Discovery

The sequence of events was as follows:

1. A private "bush" pilot, the late Bob Baker, based in Kotzebue, was engaged in part-time prospecting in northwestern Alaska, in the early 1950s, and observed some conspicuously red-orange colored creek beds, banks, and slopes in the Wulik River drainage of the DeLong Mountains area. Unable to land his fixed-wing aircraft near the stained zones, in this remote terrain, he reported his observations to U.S. Geological Survey (USGS) personnel who occasionally flew with him elsewhere in the region.

   At the time, the USGS was carrying out regional reconnaissance mapping of the DeLong Mountains quadrangle and adjoining areas, as well as other work across the region. Baker suggested that the USGS visit these colored zones via helicopter, when they might have the opportunity.

2. Such opportunity arose in 1968, during the course of other USGS work involving petroleum and oil shales, and was due principally to personal initiative on the part of one geologist, I. Tailleur. As described in the subsequent (Tailleur, 1970) brief USGS report:

   "The locality in Red Dog Creek was selected for inspection solely because it was closer to the helicopter path than any other at the time. It was examined hastily along a foot traverse eastward from the tundra-covered divide along the bright-colored spur, and down to the main creek...

   "A few outcrops rise from the tundra in the upper part of the spur, bright orange-red soil forms the crest and slope of the middle part, and ledges and talus form the foot of the spur...

   "Intense weathering is evident. The orange and hematite-red soil appear to have derived from baritic and siliceous rocks like those in fragments on the surface. Some of the fragments have been leached to siliceous cinders. Minute grains of dark sulfide were discernible on freshly broken surfaces of the baritic rock. The black chert near creek level is highly iron-stained and is locally strongly leached.

"Stream beds are coated with limonitic gel...

"Hand specimens of float were collected to represent the various rock types. Nine samples, including one of the stream sediment in Red Dog Creek, were submitted for semiquantitative spectrographic analysis. The silver and gold contents were obtained by atomic absorption methods. The results...show a range in lead content from 0.5 to more than 2.0 percent, accompanied by values of zinc that range in excess of 1.0 percent. All samples show anomalously high barium, doubtless attributable to barite which is megascopically visible in all cases...

"Because of the unusually high value reported for lead in the stream sediment sample from Red Dog Creek,...that sample was reanalyzed for lead by atomic absorption. The result indicated in excess of 10 percent (more than 100,000 ppm) Pb...

"Systematic prospecting should determine if the mineralization has regional significance and has resulted in deposits of possible economic importance."

In recognition of the assistance of the Kotzebue pilot in first recognizing the area and its potential significance, the USGS named Red Dog Creek for the pilot's pet red dog, Baker's frequent companion on bush flights.

3. No further investigations are known to have been made of the Red Dog Creek area until 1975. Subsequent to the enaction of the Alaska Native Claims Settlement Act (ANCSA), the U.S. Bureau of Mines (USBM) had been directed by the U.S. Congress to carry out investigations of the nature and resource potential of known or reported occurrences of mineralization across broad regions of federal lands in Alaska which had been withdrawn from mineral claim-staking by ANCSA (the so-called "d-2 lands").

   As part of these investigations, in 1975 the USBM initiated a program of systematic field and laboratory work to characterize and evaluate known mineral resources or geochemical anomalies across a major portion of the western Brooks Range and adjacent areas. This included the Wulik River and Red Dog Creek areas. The work was done principally via contract to private sector entities with relevant experience and expertise, directed and supplemented by USBM personnel.

It should be noted that the funds made available to the USBM for this work amounted to approximately four percent of the level

considered to be minimally adequate, on a per-acre basis, for technically substantive mineral resource exploration (exclusive of subsurface sampling) by experienced and competent private sector organizations.

In fact, the level of funding resulted in coverage of these withdrawn Alaskan lands at a level of approximately 20 percent of that considered by the United Nations to be the minimum necessary to categorize lands as other than "essentially unexplored."

Additionally, the USBM program was restricted to surface sampling only, so that "visual impacts" to these withdrawn lands would not result. Although not formally involved, I.Tailleur was consulted prior to project work. Knowledgeable personnel from the Alaska Division of Geological and Geophysical Surveys also contributed informally to the USBM work in various ways, including limited field work and consultations. In particular, R. Schaff, the Alaska State Geologist at that time, was personally active with USBM field parties at Red Dog and elsewhere.

The initial field work (July 1975) in Red Dog Creek and environs by USBM (D. Banister, mining engineer; T. Mowatt, geologist) and its contractor, WGM, Inc. (C. Bigelow, Vice President; C. Degenhart, party chief) immediately established the existence of potentially very significant mineralization, the delineation and determination of magnitude of which would require appreciable further evaluation. The contractor's initial (1975) report to the USBM stated (WGM, 1978): "This is a very impressive prospect - a number of outcrops containing high values in lead, zinc, silver and barite are are present over a length of 9,000 feet and a width of 3,500 feet...

"In addition, there are areas of high grade rubble at the surface that indicate similarly mineralized bedrock is present under thin talus. Outcrops typically carrying five to 20 percent combined zinc and lead (and) two oz./ton silver are widely distributed...

"In addition to the outcropping mineralization referred to above, a strongly anomalous area of 3.5 square miles has been outlined through geochemical stream silt sampling. A preliminary electromagnetic survey conducted to the west of outcropping mineralization has disclosed presence of a conductor. The conductor may reflect the presence of sulfides inasmuch as no graphite has been noted. If the response is due to sulfides, the overall potential is enhanced.

"Additional work is strongly recommended at Red Dog and at similar geologic environments in the west Brooks Range. Regional work should consist of geological mapping, geochemical stream silt sampling, and prospecting. Work at Red Dog should be directed toward diamond core drilling of sufficient detail to define the tonnage/grade configuration of the mineralization. The dimensions of the surface target area and the grade of mineralization are of a magnitude which, if confirmed by additional investigation, would likely warrant production...

"The Red Dog prospect is considered to be the most impressive surface mineral showing in the Brooks Range and perhaps in Alaska."

B. Delineation and Characterization

1. On the basis of this information, USBM project personnel recommended that detailed follow-up work be done, including core-drilling and geophysical surveys to delineate subsurface relationships and extent of mineralization. However, federal government policy current at that time was interpreted, at a high administrative level, to preclude drilling.

   The USBM program was restructured, and projects initiated to pursue surface work in detail sufficient to more clearly define the mineral resource potential of the Red Dog area. This included arrangements with universities to assist faculty and graduate student research, including detailed mapping and sampling, together with complementary mineralogy, petrology, and geochemistry studies. The results have been recorded by a number of contributions to the technical literature since 1975 by agency and academic participants.

2. After a fair amount of political and bureaucratic maneuvering, in 1976, the Red Dog Creek area and environs were made part of the preliminary selections of land to which the NANA Regional Corporation was entitled, as stipulated by ANCSA. Selection of lands, including these areas, was in large part due to the information developed and quickly made available to the public during the USBM program. The Red Dog deposit already was being described as "potentially world class."

   Subsequent detailed studies were carried out by the private sector, and in 1982, the NANA Corporation and a major mining company (Cominco) with appreciable experience in northern latitudes and base-precious metal production worked out a long-

term agreement for the development of the Red Dog deposit. Subsequent activities have featured development of design concepts and facility studies, completion of environmental studies, initiation of detailed engineering, and construction of mine-mill plants, as well as transportation facilities. The latter include a road some 54 miles to the sea coast and port facilities.

The road (*Figure 4*, from Giegerich, 1986) is routed partly through Cape Krusenstern National Monument, hence federal government approval, at the Congressional level, was required. This was obtained in 1985, via special legislation, due to recognized collective socio-economic benefits of development of the deposit to the corporations, the state of Alaska, and the nation.

The state of Alaska has recognized these benefits, additionally, by developing a multiple-use transportation system in the DeLong Mountains area. The state has financed, built, and is operating significant portions of the system, with charges for its use. This action appreciably eased the financial burdens which would have been presented to the private sector firms prior to their establishing cash flows attendant to ore production.

Initial shipments of ore concentrates commenced in 1990, at which time the Red Dog mine began its' evolution into perhaps the largest base metal mine in the world.

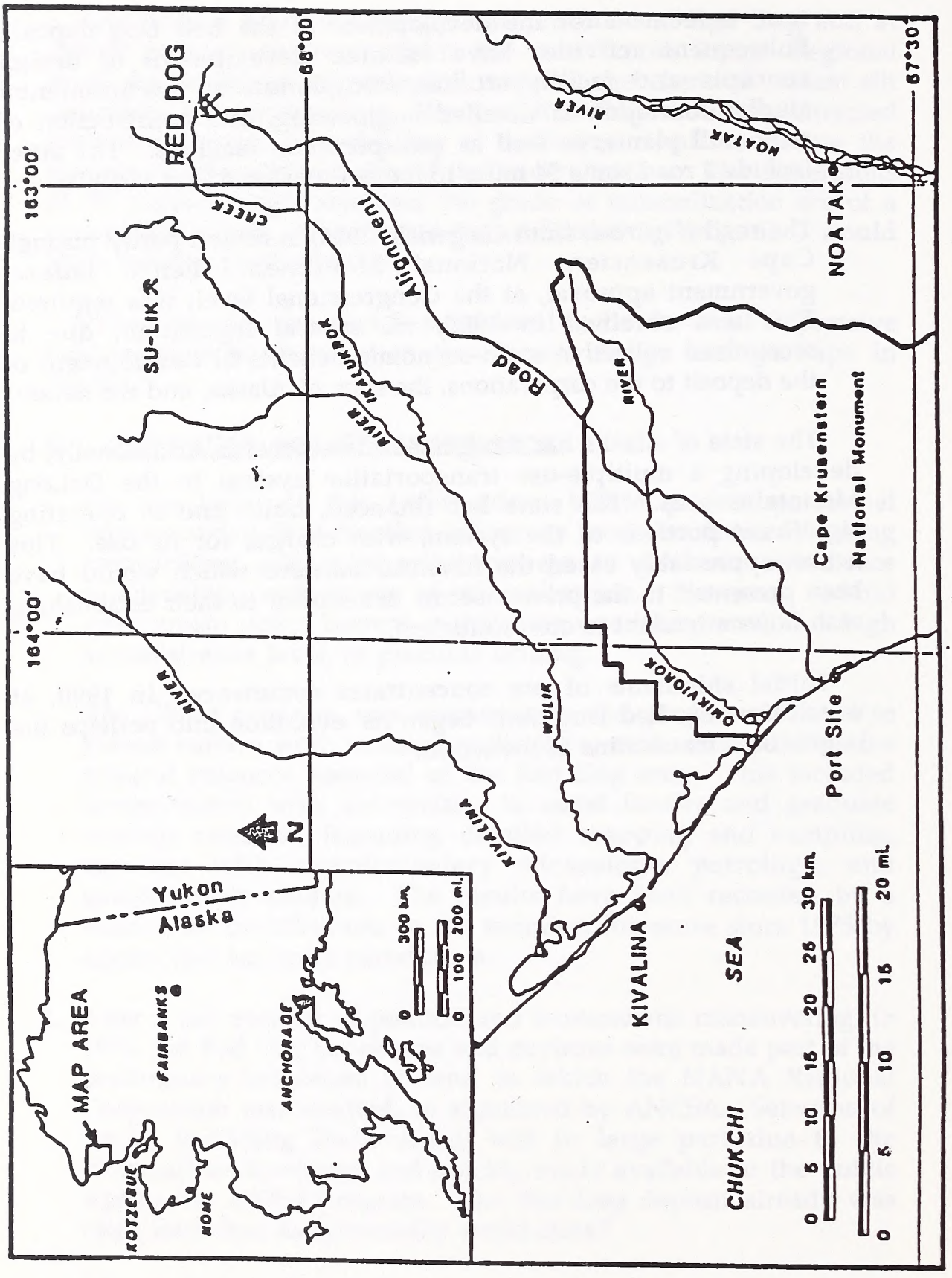

Figure 4. Road alignment from the Red Dog deposit to the sea coast port (from Giegerich, 1986).

4. Conclusion

Thus, despite occasional problems attendant to interfacing and defining/clarifying roles, the overall results indicate a relatively effective meshing of government organizations, private and academic sectors, during the lengthy course from discovery to development to production of an important mineral deposit. Each played a role appropriate to its responsibilities, interests, and capabilities, in reasonably complementary fashion.

A substantial amount of new mineral resources has been made available to global society, with attendant socio-economic benefits. The sequence of events and the period of time (early 1950s to 1990) elapsed are testimony to the realities of an accomplishment of this magnitude.

As debate continues as to future sources-kinds-magnitudes-availabilities of mineral resources, development-use-consumption, other resources/land-use values and considerations, government-private sector roles, etc., perhaps the history of the Red Dog example will provide some useful insights.

By way of contrast, mineralization quite similar in aspect to that at Red Dog has been recognized in analogous geologic settings in a number of places elsewhere in northwestern Alaska. The geologic terrane which hosts the Red Dog deposit trends north and east from the Wulik River area, across adjacent portions of the Noatak National Preserve (established subsequent to the 1975 recognition of the Red Dog deposit), and the southern portion of the National Petroleum Reserve in Alaska (NPRA), continuing on far to the east in a somewhat ill-defined regional belt. *Figures 2 and 3* illustrate this.

A number of base and precious metals (principally zinc, lead, silver) mineral occurrences, as well as extensive geochemical anomalies (zinc, lead, arsenic, barium, silver, chromium) were recognized by reconnaissance studies by the USBM and USGS during 1977-1978 (Janson, 1982). Five distinct geochemical and geological associations have been identified within this belt. To date, at least four zones of significant base metal mineralization have been elucidated: (1) Drenchwater Creek; (2) Kivliktort Mountain; (3) Story Creek; (4) Whoopee Creek.

Particularly interesting is the occurrence at Drenchwater Creek, some 100 miles to the east of Red Dog. The Drenchwater Creek locality has been studied and reported on by federal agencies (USGS,

USBM) in similar fashion to the preliminary work described for Red Dog.

There is a major difference, however, in that Drenchwater Creek and environs, as well as most of the other occurrences/anomalies, lie within the NPRA, which has been closed to private sector mineral claim-staking for many years. Thus, the subsequent follow-up work required to determine the presence or absence of viable mineral deposits has not been done. Given the present land status and federal policy, development is precluded, hence potentially significant mineral resources remain recognized, but unevaluated.

Additionally, large areas of land between the Red Dog area and the Drenchwater Creek/southern NPRA area, as well as to the south, have been removed from mineral resource exploration-development by incorporation into the Noatak National Preserve and Gates of the Arctic National Park. There are many similarities in geologic relationships across the region, but sufficient work to substantively assess mineral resource potential was not done prior to the designation of the Noatak National Preserve and Gates of the Arctic National Park. No work of this nature has been done since, of course. This situation needs to be addressed in terms of the socio-economic context in order for the required technical work to proceed.

5. References

Einaudi, M. and W. Hitzman, 1986, Mineral deposits in northern Alaska: Introduction: Economic Geology, v. 81, p. 1583-1591.

Geigerich, H., 1986, Progress report on Cominco's Red Dog project in Alaska, second largest zinc deposit ever discovered: Mining Engineering, p.1097-1101.

Jansons, U., 1982, Zinc-lead occurrences in and near the National Petroleum Reserve in Alaska: U.S. Bureau of Mines MLA 121-82, 55 p.

Lange, I., W. Nokleberg, J. Plahuta, H. Krouse, B. Doe, 1985, Geologic setting/petrology, and geochemistry of stratiform sphalerite-galena-barite deposits, Red Dog Creek and Drenchwater Creek areas, northwestern Brooks Range, Alaska: Economic Geology, v. 80, p. 1896-1926.

Moore, D., L. Young, J. Modene, and J. Plahuta, 1986, Geologic setting and genesis of the Red Dog zinc-lead-silver deposit, western Brooks Range, Alaska: Economic Geology, v. 81, p. 1696-1727.

Mowatt, T. C., 1989, Red Dog mineral deposit, northwest Alaska: Discovery, delineation and government-private sector interaction: (abs.) Twenty-Eighth International Geological Congress, Washington, D. C., v. 2, p.2-472-473.

Mowatt, T. C., J. Dygas, and C. Gibson, 1990, Red Dog mineral deposit, northwest Alaska: Discovery, delineation, and implications for other resources regionally: (abs.) Bulletin of the American Association of Petroleum Geologists, v. 74, p. 993-994.

Tailleur, I., 1970, Lead-, zinc-, and barite-bearing samples from the western Brooks Range, Alaska: U.S. Geological Survey Open-File Report 445.

WGM, Inc., 1978, United States Bureau of Mines J0155089 mineral studies of certain ANCSA 17(d)(2) lands in Alaska: U.S. Bureau of Mines Open-File Report 103-78.

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